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<b>(54) Title:</b> MICROFILLED DENTAL COMPOSITE AND METHOD USING THE SAME  <b>(57) Abstract</b>  A filled-resin dental composite. The filler is a mixture of hydrophobic silica particles about 0.01 to 0.04 micron in diameter and glass particles about 2 to 30 microns in diameter. Preferably, the glass is x-ray opaque. An improved method for restoring carious lesions in a living tooth is presented, using the composite.		

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1.  
S P E C I F I C A T I O N  
MICROFILLED DENTAL COMPOSITE AND METHOD USING THE SAME

This invention relates to a microfilled dental composite and to a method employing it.

Heretofore the fillers in dental composites have been composed of particles from about 0.5 micron to about 150 microns in diameter. These relatively large particles have resulted in a rougher type of finish than many practitioners desire. Yet, although some manufacturers used a small amount of submicron filler particles, which are typically 0.02 to 0.04 micron in diameter (to eliminate settling, for example), they have used them only up to about 5% by weight of the composite, and most of the particles remained relatively large.

Recently, various manufacturers have placed on the market "microfilled" composites in which all of the filler was in the 0.02 to 0.04 micron range, and a smoother finish was thereby obtained. However, when using these small-particle fillers, only about 25% to 50% of the composite could be filler. This fact led to the disadvantage that the overall composite exhibited a much greater cure shrinkage than previous composites using large-particle fillers, so that the composite tended to pull away from the teeth as it cured. Such composites have also had a higher coefficient of thermal expansion and higher water sorption than those of the regular composites containing larger sized particles.

Summary of the Invention

The present invention provides a microfilled dental composite containing from about 30% to about 83.5% filler, and the filler is a mixture of (1) sub-micron hydrophobic silica particles about 0.01-0.04 micron in diameter and (2) glass particles in the range of 2 to 30 microns. Weightwise the glass is present in amounts equal to or in excess of the sub-micron filler; however, due to the density differences, most of the filler, in terms of volume, is sub-micron hydrophobic silica. Preferably, the glass should contain barium or strontium, to render it x-ray opaque.

An important result obtained by this new composite is that it gives a much smoother finish than do regular composites. Although this finish may not be quite as smooth as

## 2.

can be obtained by the best of the microfilled composites when examined with a scanning electron microscope, the smoothness is quite adequate clinically, and the composition is better overall, for, in contrast to the microfilled products, the chemical and mechanical properties of this new dental composite are not significantly degraded in relation to the conventional composites.

Moreover, there is another advantage, in that the new material is opaque to x-rays, and the regular microfilled compositions are not.

#### Examples of Preferred Embodiments

The system is preferably prepared and stored as a two-paste system with all compositions being present in the two pastes in identical proportions, except that in one of the pastes there is a curing agent or catalyst (e.g., benzoyl peroxide) and in the other paste there is an accelerator, such as 2-hydroxyethyl-p-toluidine. Just before use, the two halves are mixed together and immediately start curing, so that they are emplaced at once.

#### Example 1

A formulation system embodying this invention comprises the following illustrative ranges:

<u>Component</u>	<u>Parts by Weight</u>
Ethoxylated bisphenol A dimethacrylate	53.00 - 17.5
Triethylene glycol dimethacrylate	4.00 - 13.5
Ultra-violet light absorbent (e.g. 2-hydroxy-4-methoxy benzophenone)	0.4 - 1.4
Anti-oxidant. (e.g. butyl hydroxy toluene)	0.15 - 0.5
Curing agent (e.g. benzoyl peroxide)	0.25 - 1.00
Cure accelerator (e.g. 2-hydroxyethyl-p-toluidine)	0.25 - 1.00
Sub-micron hydrophobic silica particles	10.00 - 30.00
Glass particles	20.00 - 67.00

The sub-micron hydrophobic silica may be Degussa's Aerosil, R 972, which has a particle range of 0.01 to 0.04 microns, with an average particle size of approximately 0.02

## 3.

micron ( $20 \times 10^{-7}$  cm). The basis for the manufacture of hydrophobic silica is a very pure form of silicon dioxide aerosol obtained by flame hydrolysis. Its particles vary in diameter between 10 and 40  $\mu$ . On each 100 sq meters of surface area, it has about 0.5 millimol silanol groups; hence it is hydrophilic. On its surface there is a one silanol group per  $28-33 \text{ \AA}^2$  ( $\equiv \text{Si-OH}$ ). Hence, with 200 square meters per gram specific surface area, there are about  $6.2 \times 10^{20}$  silanol groups per gram, i.e., one millimol. This gives a figure of about 2000 silanol groups per particle.

In a continuous process, some 75% of these silanol groups can be chemically reacted with dimethyl dichlorosilane, the resultant product having about 0.7 millimol of chemically combined methyl groups per 100 square meters of surface area. The silica when thus reacted becomes hydrophobic and behaves differently in organic liquids from the hydrophilic material. For this purpose, freshly obtained hydrophilic silica is separated from the bulk of the hydrochloric acid formed in the flame hydrolysis. Then, this silica, dimethyl dischlorosilane, and steam are pneumatically fed in parallel flow into a fluidized bed reactor heated to about  $400^\circ\text{C}$  by means of an inert gas such as nitrogen. Besides the chemical reaction of the chlorosilane with the silanol groups of the surface, the desorption of the hydrochloric acid resulting from the reaction takes place in the reactor in a continuous stream, so that there is an analytically assessable chlorine content of below 0.03%. The main quantity of hydrochloric acid is removed from the freshly manufactured  $\text{SiO}_2$  and the material does not yet contain any absorbed water. Moreover, siloxane bridges still exist on the surface of the particles, these having formed at the high temperatures used in the process. These bridges break up in the presence of water vapor and chlorosilane in the reaction zone, whereupon the reaction can take place in the nascent state of the silanol group formation.

Analytical data and moisture absorption data of hydrophobic silica are given in Tables 1 and 2 respectively.

4.

Table 1. Analytical data on hydrophobic AEROSIL R 972:

SiO <sub>2</sub> + (-CH <sub>3</sub> )	99.8%
surface area (acc. to <u>Brunauer, Emmet &amp; Teller</u> )	120 ± 30 m <sup>2</sup> /g
average particle size	20 ± 10 <sup>-7</sup> cm
carbon	1.1 ± 0.2%
pH value (4% dispersion methanol/water 1:1)	3.8 ± 0.2
chlorine content	0.04 ± 0.01%
heavy metals	0.003%
As	0.0001%
Fe <sub>2</sub> O <sub>3</sub>	0.003%
Al <sub>2</sub> O <sub>3</sub>	0.05%
TiO <sub>2</sub>	0.03%
Na <sub>2</sub> O	0.01%
bulk density	about 40-60 g/l
compacted volume	about 20 ml/g

Table 2. Moisture adsorption in mg/100 m<sup>2</sup>

Relative air humidity in %	20	40	60	80
Hydrophilic silica	1.3	4.0	10	30
Hydrophobic silica	0.3	0.4	0.9	1.5

The glass particles are preferably x-ray opaque and for that reason preferably contain barium or strontium. The ratio of glass particles to silica particles may vary from about 1:2 to 3:1.

A preferred barium-containing glass may be Kimble's Ray-Sorb T-2000, which has a particle range of 2 to 30 microns, as shown in Table 3.

Table 3. Particle Size Distribution of Ray-Sorb T-2000

<u>Size</u>	<u>Specification</u>
2 microns	85 - 100% greater
5 "	60 - 85% "
10 "	35 - 60% "
20 "	10 - 25% "
30 "	0 - 10% "

This material has the following properties:

Refractive Index: 1.58

Thermal Expansion: 6.7 ppm/°C (0-38°C)

Density: 3.4 g/cc

## 5.

Another suitable radiopaque filler is Kimble's Ray-Sorb T-3000, which has the same particle size distribution as that in Table 3 and which has the following somewhat different properties:

Refractive Index: 1.557

Thermal Expansion:  $44.4 \times 10^{-7}$  (0-38°C)

Density: 3.049 g/cc

A third suitable radiopaque filler, Ray Sorb T-4000, also has the same particle size distribution.

A filler which is not radiopaque is structurally as satisfactory, lacking only the disadvantage of not being radiopaque. For example, Kimble's Cer-Vit T-1000 has the same particle size distribution as that of Table 3 and the following properties:

Thermal Expansion: -2.3 ppm/°C (0-38°C)

Refractive Index: 1.54

Density: 2.5 g/cc

The 2-hydroxyethyl-p-toluidine (HEPT) is an accelerator. Other accelerators which may be used include N, N-3, 5-tetramethylalanine at about half the concentration of HEPT and N, N-dimethyl-p-toluidine at about one quarter to one half of the concentration of HEPT given above.

Benzoyl peroxide is a curing agent. Other organic peroxide curing agents may be used. Ultra-violet curing agents such as benzoin methyl ether may also be used, in which case no ultra-violet absorber is included.

The 2-hydroxy-4-methoxy benzophenone is an ultra-violet-light absorbent and may be UV-5411.

#### Example 2

Some other systems have been tried in which the ethoxylated bisphenol A dimethacrylate is replaced by Bis-GMA. An example of this is as follows:

	<u>Parts by Weight</u>
Bis-GMA	36.
Triethylene glycol dimethacrylate	24.
Sub-micron hydrophobic silica	20.
Barium-containing glass	20.



6.

Example 3

	<u>Parts by Weight</u>
Bis-GMA	28.6
Triethylene glycol dimethacrylate	19.0
Sub-micron hydrophobic silica	14.3
Barium-containing glass	38.1

Other examples using the resins of Example 1 follow:

Example 4

Triethylene glycol dimethacrylate	11.27
Ethoxylated Bisphenol A dimethacrylate	16.90
Sub-micron hydrophobic silica	19.72
Barium-containing glass	52.11

Example 5

Ethoxylated bisphenol A dimethacrylate	21.31
Triethylene glycol dimethacrylate	5.33
2-hydroxy-4-methoxybenzophenone	0.53
Butyl hydroxy toluene	0.18
Benzoyl peroxide	0.40
2-hydroxyethyl-p-toluidine	0.40
Sub-micron hydrophobic silica	20.00
Barium-containing glass	52.00

When used as a two-paste system, each of the two pastes contains half of the amounts shown in each example, except that only one of the two pastes contains the benzoyl peroxide and the other one includes the 2-hydroxyethyl-p-toluidine. The two pastes may be stored and are mixed just prior to application and applied at once; they set at a gel in about one and one-half to two and one-half minutes.

The material of Example 5 has been compared with one excellent non-microfilled dental composite and with four competing microfilled composites. The test results are shown in Table 4:

6. a

TABLE 4

	Time For Gel Set (Seconds)	Compressive Strength (psi)	Cure Shrinkage (%)	Thermal Expansion (ppm/°C)*	Water Sorption (mg/cm <sup>2</sup> )	Color Stability	X-Ray Opacity
An excellent non-microfilled dental composite	120/150	36000	0.92	22	0.45	Exc.	Yes
The dental composite of this invention	120/150	36000	0.71	29	0.45	Exc.	Yes
1st competing microfilled composite	120/143	**	1.29	55	1.33	Poor	No
2nd Competing microfilled composite	113/175	27000	1.16	76	2.10	Med	No
3rd Competing microfilled composite	113/175	27000	1.16	76	2.10	Med	No
4th competing microfilled composite	102/134	33000	0.84	46	1.22	Med	No

\* Over range of 5°-55°C

\*\* Material very soft, changes cross-section prior to rupture- unable to measure.

## 7.

As these tests show, the compressive strength of the dental composite of this invention is substantially greater than that of the four competing microfilled composites and equal to that of an excellent non-microfilled composite. The cure shrinkage is lower than that of any of the microfilled composites -- much less than three of them -- and is less than that of the non-microfilled composite tested. Thermal expansion is not much greater than that of the tested non-microfilled composite and much less than that of any of the microfilled composite. Water sorption is equal to that of the non-microfilled composite and very much less than that of the competing microfilled composites. Furthermore, color stability is excellent, and the composite is opaque to x-rays.

An advantage of this invention is that the consistency of the highly filled material, when the total filler content is about 30% to 83.5% of the total composite, is such that the dentist can use an amalgam carrier for putting it into the cavity. This is much more convenient than the instruments customarily used to place composite restoratives.

Water sorption with the system is below  $0.5 \text{ mg/cm}^2$ , even with only 30% filler. It remains low throughout the filler range at every concentration tested up to 72% total filler with 2.6:1 barium glass:submicron silica.

The compressive strength measured 36,000 p.s.i. at 56% total filler and 2:1 barium glass:aerosil. It remained at 36,000 at 72% total filler and 2.6:1 barium glass:submicron silica.

All samples tested gave less than 0.8% shrinkage. A test with 72% total filler at 2.6:1 barium glass:aerosil gave 0.71% shrinkage.

With 56% filler at 2:1 barium glass:submicron silica, the thermal expansion is  $28.85 \text{ ppm/}^\circ\text{C}$ . With 72% filler at 2.6:1 barium glass:submicron silica, the thermal expansion is  $29 \text{ ppm/}^\circ\text{C}$ .

The radiopaquing effect of the barium glass becomes useful at about 20% barium glass, regardless of total filler concentration.

8.

the cavity and placing retention in the dentin, or (2) by isolating the tooth (i.e., by a rubber dam with a hole for that tooth) and then polishing with pumice to remove plaque and debris, following by washing and drying, and then etching for one or two minutes, typically with 30% to 50% phosphoric acid solution.

In either event, the cavity is then cleaned, as by washing, and is then dried with air, preferably using a drying agent to assist and speed up the drying. Then a bonding agent is applied to the surface of the cavity; this may be a suitable bonding resin of known type. The excess resin is then blown out.

The microfilled dental composite of this invention is then applied, freshly mixed. The cavity is somewhat overfilled, i.e. the composite is applied in excess, using a matrix or other aid where needed to achieve accurate molding. It is then allowed to harden. When it is hardened, the composite is then finished as by diamond, etc., grinding off the excess.

This material may also be utilized as a veneering paste in the laboratory. For example, a cast gold crown was prepared to accept a plastic veneer, utilizing procedures well known to dental laboratory technicians. A veneer was fashioned, utilizing a material like that in Example 5, except that it contained only the peroxide half of the peroxide-amine curing system. The resultant preparation was heat-cured in a dental flask at 100 p.s.i. pressure and at 115°C for one half hour. The resultant veneer was very hard, smooth, impervious to fluids, and lifelike in appearance. It is possible to prepare special tinted versions of this paste in order to duplicate incisal or dentinal shadings as is commonly done by the dental technician with those materials now used for this purpose.

What is claimed is:

9.

1. A filled-resin dental composite wherein the filler consists essentially of a mixture of submicron particles of hydrophobic silica, ranging from about 0.01 micron to 0.04 micron in diameter, and glass particles ranging from about 2 microns to about 30 microns in diameter.

2. The dental composite of claim 1, wherein the average particles size of the glass particles is about seven microns.

3. The dental composite of claim 1 wherein the glass is x-ray opaque.

4. The dental composite of claim 3 wherein the glass contains a barium salt.

5. The dental composite of claim 3 wherein the glass contains a strontium salt.

6. The composite of claim 1 wherein the silica is present in the amount of 10% to 30% by weight of the composite and glass is present in amounts from 20% to 67% of the total composite, with the filler total being from about 30% to about 83.5% by weight.

7. A filled dental composite consisting essentially of 16.5% to 75% by weight of suitable resin with curing agent and accelerator and 25% to 83.5% by weight of filler consisting essentially of a mixture of hydrophobic silica particles ranging from about 0.01 micron to 0.04 micron in diameter and glass particles ranging from about two to thirty microns in diameter.

8. The dental composite of claim 7 wherein the glass is x-ray opaque.

9. A filled-resin dental composite consisting essentially of

<u>Component</u>	<u>Parts by Weight</u>
Ethoxylated bisphenol A dimethacrylate	53 - 17.5
Triethylene glycol dimethacrylate	4 - 13.5
Cure accelerator	0.4 - 1.4
Antioxidant	0.15 - 0.5
Curing agent	0.25 - 1.0
Ultra violet light absorbent	0.25 - 1.0
Sub-micron hydrophobic silica particles	10 - 30

10.

the silica particles ranging from about 0.1 micron to 0.04 micron in diameter and the glass particles ranging from about two to about thirty microns in diameter.

10. The dental composite of claim 9 wherein the glass is x-ray opaque.

11. A veneering dental paste for heat curing consisting essentially of 16.5% to 75% by weight of suitable resin with peroxide curing agent and no amine and 25% to 83.5% by weight of filler consisting essentially of a mixture of hydrophobic silica particles ranging from about 0.01 micron to 0.04 micron in diameter and glass particles ranging from about two to thirty microns in diameter.

12. The dental paste of claim 11 wherein the glass is x-ray opaque.

13. A veneering dental paste for heat curing consisting essentially of

<u>Component</u>	<u>Parts by weight</u>	
Ethoxylated bisphenol A dimethacrylate	53	- 17.5
Triethylene glycol dimethacrylate	4	- 13.5
Antioxidant	0.15	- 0.5
Benzoyl peroxide	0.25	- 1.00
Ultra-violet light absorbent	0.25	- 1.00
Sub-micron hydrophobic silica particles	10	- 30
Glass particles	20	- 67,

the silica particles ranging from about 0.01 micron to 0.04 micron in diameter and the glass particles ranging from about two to about thirty microns in diameter.

14. The dental paste of claim 13 wherein the glass is x-ray opaque.

15. A filled-resin composite consisting essentially of

11.

<u>Component</u>	<u>Parts by Weight</u>	
Ethoxylated bisphenol A dimethacrylate	53	- 17.5
Triethylene glycol dimethacrylate	4	- 13.5
2-hydroxy-4-methoxy benzophenone	0.4	- 1.5
Butyl hydroxy toluene	0.15	- 0.5
Benzoyl peroxide	0.25	- 1.0
2-hydroxyethyl-p-toluidine	0.25	- 1.0
Sub-micron hydrophobic silica particles	10	- 30
Barium-containing glass particles	20	- 67,

the particles size of the silica being in the range of about 0.01 - 0.04 micron and the particle size of the glass in the range of about two to thirty microns, averaging about seven microns.

16. A microfilled dental composite consisting essentially of

<u>Ingredient</u>	<u>Approximate Parts by Weight</u>
Ethoxylated bisphenol A dimethacrylate	21
Triethylene glycol dimethacrylate	5
2-hydroxy-4-methoxybenzophenone	0.5
Butyl hydroxy toluene	0.2
Benzoyl peroxide	0.4
2-hydroxyethyl-p-toluidine	0.4
sub-micron hydrophobic silica particles	20
Glass particles	52,

the particle sizes of the fillers being approximately:

silica 0.01 - 0.04 micron  
glass 2 - 30 microns.

17. The dental composite of claim 16 wherein the glass contains a barium compound in an amount to render it x-ray opaque.

18. A microfilled dental composite consisting essentially of

<u>Ingredient</u>	<u>Approximate Parts by Weight</u>
Triethylene glycol dimethacrylate	11
Ethoxylated bisphenol A dimethacrylate	16.9
Sub-micron hydrophilic silica particles	19.7
Glass particles	52.1,

the particle sizes being approximately:

12.

silica 0.01 - 0.04 micron  
 glass 2 - 30 microns.

19. The dental composite of claim 18 wherein the glass is x-ray opaque.

20. A microfilled dental composite consisting essentially of

<u>Component</u>	<u>Approximate Parts by Weight</u>
Bis-GMA	36
Triethylene glycol dimethacrylate	24
Sub-micron hydrophobic silica particles	20
Glass particles	20,

the particle sizes being approximately:

silica 0.01 - 0.04 micron  
 glass 2 - 30 microns.

21. The dental composite of claim 20 wherein the glass is x-ray opaque.

22. A method for restoring carious lesions in a living tooth, comprising

preparing a cavity for reception of the restoration including cleaning and drying it,

applying a bonding resin to the surface area of the cavity,

removing excess resin from the cavity,

applying in excess to the cavity a composite consisting essentially of a mixture of:

<u>Ingredient</u>	<u>Approximate Parts by Weight</u>
Resin, with curing agent & accelerator.	75 - 16.5
Filler	25 - 83.5

said filler being a mixture of 10 to 30 parts by weight of submicron hydrophobic silica particles about 0.01 - 0.04 micron in diameter and up to 67 parts by weight of glass particles about 2 to 30 microns in diameter,

curing said composite to hardness sufficient to withstand grinding, and

abrasively reducing the excess to the desired amount.



## AMENDED CLAIMS

(received by the International Bureau on 14 July 1981 (14.07.81))

1. A filled-resin dental composite wherein the filler consists essentially of a mixture of submicron particles of hydrophobic silica, ranging from about 0.01 micron to 0.04 micron in diameter, and glass particles ranging from about 2 microns to about 30 microns in diameter.
2. The dental composite of claim 1, wherein the average particles size of the glass particles is about seven microns.
3. The dental composite of claim 1 wherein the glass is x-ray opaque.
4. The dental composite of claim 3 wherein the glass contains a barium salt.
5. The dental composite of claim 3 wherein the glass contains a strontium salt.
6. The composite of claim 1 wherein the silica is present in the amount of 10% to 30% by weight of the composite and glass is present in amounts from 20% to 67% of the total composite, with the filler total being from about 30% to about 83.5% by weight.
7. A filled dental composite consisting essentially of 16.5% to 75% by weight of suitable resin with curing agent and accelerator and 25% to 83.5% by weight of filler consisting essentially of a mixture of hydrophobic silica particles ranging from about 0.01 micron to 0.04 micron in diameter and glass particles ranging from about two to thirty microns in diameter.
8. The dental composite of claim 7 wherein the glass is x-ray opaque.
- (amended) 9. A filled-resin dental composite consisting essentially of

<u>Component</u>	<u>Parts by Weight</u>
Ethoxylated bisphenol A dimethacrylate	53. - 17.5
Triethylene glycol dimethacrylate	4. - 13.5
Cure accelerator	0.25 - 1.0
Antioxidant	0.15 - 0.5
Curing agent	0.25 - 1.0
Ultra violet light absorbent	0.4 - 1.4
Sub-micron hydrophobic silica particles	10. - 30.
Glass particles	20. - 67.

the silica particles ranging from about 0.1 micron to 0.04 micron in diameter and the glass particles ranging from about two to about thirty microns in diameter.

10. The dental composite of claim 9 wherein the glass is x-ray opaque.

11. A veneering dental paste for heat curing consisting essentially of 16.5% to 75% by weight of suitable resin with peroxide curing agent and no amine and 25% to 83.5% by weight of filler consisting essentially of a mixture of hydrophobic silica particles ranging from about 0.01 micron to 0.04 micron in diameter and glass particles ranging from about two to thirty microns in diameter.

12. The dental paste of claim 11 wherein the glass is x-ray opaque.

13. A veneering dental paste for heat curing consisting essentially of

<u>Component</u>	<u>Parts by weight</u>
Ethoxylated bisphenol A dimethacrylate	53 - 17.5
Triethylene glycol dimethacrylate	4 - 13.5
Antioxidant	0.15 - 0.5
Benzoyl peroxide	0.25 - 1.00
Ultra-violet light absorbent	0.25 - 1.00
Sub-micron hydrophobic silica particles	10 - 30
Glass particles	20 - 67,

the silica particles ranging from about 0.01 micron to 0.04 micron in diameter and the glass particles ranging from about two to about thirty microns in diameter.

14. The dental paste of claim 13 wherein the glass is x-ray opaque.

15. A filled-resin composite consisting essentially of

<u>Component</u>	<u>Parts by Weight</u>	
Ethoxylated bisphenol A dimethacrylate	53	- 17.5
Triethylene glycol dimethacrylate	4	- 13.5
2-hydroxy-4-methoxy benzophenone	0.4	- 1.5
Butyl hydroxy toluene	0.15	- 0.5
Benzoyl peroxide	0.25	- 1.0
2-hydroxyethyl-p-toluidine	0.25	- 1.0
Sub-micron hydrophobic silica particles	10	- 30
Barium-containing glass particles	20	- .67,

the particles size of the silica being in the range of about 0.01 - 0.04 micron and the particle size of the glass in the range of about two to thirty microns, averaging about seven microns.

16. A microfilled dental composite consisting essentially of

<u>Ingredient</u>	<u>Approximate Parts by Weight</u>
Ethoxylated bisphenol A dimethacrylate	21
Triethylene glycol dimethacrylate	5
2-hydroxy-4-methoxybenzophenone	0.5
Butyl hydroxy toluene	0.2
Benzoyl peroxide	0.4
2-hydroxyethyl-p-toluidine	0.4
sub-micron hydrophobic silica particles	20
Glass particles	52,

the particle sizes of the fillers being approximately:

silica 0.01 - 0.04 micron

glass 2 - 30 microns.

17. The dental composite of claim 16 wherein the glass contains a barium compound in an amount to render it x-ray opaque.

18. A microfilled dental composite consisting essentially of

<u>Ingredient</u>	<u>Approximate Parts by Weight</u>
Triethylene glycol dimethacrylate	11
Ethoxylated bisphenol A dimethacrylate	16.9
Sub-micron hydrophilic silica particles	19.7
Glass particles	52.1,

the particle sizes being approximately:

silica 0.01 - 0.04 micron

glass 2 - 30 microns.

19. The dental composite of claim 18 wherein the glass is x-ray opaque.

20. A microfilled dental composite consisting essentially of

<u>Component</u>	<u>Approximate Parts by Weight</u>
Bis-GMA	36
Triethylene glycol dimethacrylate	24
Sub-micron hydrophobic silica particles	20
Glass particles	20,

the particle sizes being approximately:

silica 0.01 - 0.04 micron

glass 2 - 30 microns.

21. The dental composite of claim 20 wherein the glass is x-ray opaque.

22. A method for restoring carious lesions in a living tooth, comprising

preparing a cavity for reception of the restoration including cleaning and drying it,

applying a bonding resin to the surface area of the cavity,

removing excess resin from the cavity,

applying in excess to the cavity a composite consisting essentially of a mixture of:

<u>Ingredient</u>	<u>Approximate Parts by Weight</u>
Resin, with curing agent & accelerator	75 - 16.5
Filler	25 - 83.5

said filler being a mixture of 10 to 30 parts by weight of submicron hydrophobic silica particles about 0.01 - 0.04 micron in diameter and up to 67 parts by weight of glass particles about 2 to 30 microns in diameter,

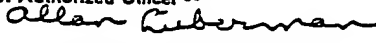
curing said composite to hardness sufficient to withstand grinding, and

abrasively reducing the excess to the desired amount.

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US81/00031

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>3</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC INT CL 3 A61K 6/08; CO8K 3/26; CO8K 3/40; CO8K9/06 US CL 260/998.11; 433/226; 433/228 106/35; 260/42.14; 260/42.52; 260/42.53		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>4</sup>		
Classification System	Classification Symbols	
US	106/35; 260/42.14, 260/42.15; 260/42.52 260/42.53; 260/998.11; 433/226; 433/228	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched <sup>5</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <sup>14</sup>		
Category <sup>6</sup>	Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No. <sup>18</sup>
A	US, A, 3770811, PUBLISHED 6 NOVEMBER 1973 LEE, JR. ET AL	1-22
A	US, A, 3926906, PUBLISHED 16 DECEMBER 1975 LEE, II ET AL	1-22
A	US, A, 4032504, PUBLISHED 28 JUNE 1977 LEE, JR. ET AL	1-22
A	US, A, 4150012, PUBLISHED 17 APRIL 1979 JOOS	1-22
P	US, A, 4220582, PUBLISHED 2 SEPTEMBER 1980 ORLOWSKI ET AL	1-22
A	AU, B, 477135, PUBLISHED 12 FEBRUARY 1976 CRANDER	1-22
* Special categories of cited documents: <sup>15</sup> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>"A" document defining the general state of the art</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document cited for special reason other than those referred to in the other categories</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> </div> <div style="width: 45%;"> <p>"P" document published prior to the international filing date but on or after the priority date claimed</p> <p>"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance</p> </div> </div>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search <sup>1</sup>	Date of Mailing of this International Search Report <sup>2</sup>	
19 MAY 1981	28 MAY 1981	
International Searching Authority <sup>1</sup>	Signature of Authorized Officer <sup>20</sup>	
ISA/US	<div style="text-align: center;">               ALLAN LIEBERMAN           </div>	

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	DE, A, 2462271, PUBLISHED 9 SEPTEMBER 1976 MICHL ET AL	1-22
A	JOURNAL OF PROSTHETIC DENTISTRY, VOLUME 42, NO. 2, ISSUED AUGUST 1979 (NEW YORK, NEW YORK) JOHN W. MC LEAN, THE FUTURE OF RESTORATIVE MATERIALS, SEE PAGES 154-156.	1-22
A	JADA, VOLUME 99, ISSUED OCTOBER 1979, C. N. RAPTIS ET AL, PROPERTIES OF MICROFILLED AND VISIBLE LIGHT-CURED COMPOSITE RESINS (PP. 631-633).	1-22

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE <sup>10</sup>

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers \_\_\_\_\_, because they relate to subject matter <sup>12</sup> not required to be searched by this Authority, namely:
2. ☐ Claim numbers \_\_\_\_\_, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out <sup>13</sup>, specifically:

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING <sup>14</sup>

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

## Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.